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BIOLOGY OF *PROSERPINUS CLARKIAE* (SPHINGIDAE)

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ABSTRACT. *Proserpinus clarkiae* (Boisduval) is a small, green, diurnal sphingid ranging widely through western North America. *Proserpinus clarkiae* larvae were reared from ova of field collected adults and the life history is herein described for the first time. *Clarkia unguiculata* (Lindley) (Onagraceae) is a larval host for *P. clarkiae*. In captivity, larvae may be reared on *Clarkia unguiculata*, *C. concinna* (Fischer & C. Meyer), and *Fuchsia* sp. (Onagraceae). Instars 1 through 4 are predominantly green with pink or fuchsia markings and are cryptic on the host. The final instar has radically different color and markings from earlier stages, as in related species and genera, and appears cryptic against senescing grasses and annual plants among which it must search for foodplants. Pupation occurs at the soil surface under solid objects

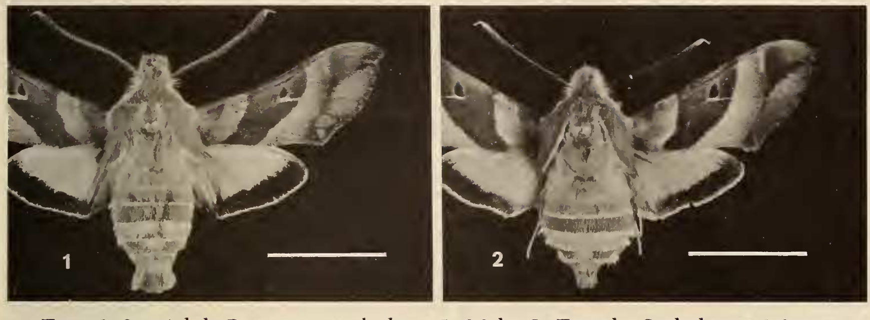
Additional key words: *Clarkia unguiculata*, *Euproserpinus*, Onagraceae, crypsis, pheromone.

Proserpinus Hübner is a predominantly North American genus that includes seven species, as currently delineated, with one species restricted to the Palearctic Region (Hodges 1971). The early stages have not been described for any American species. Partial life history descriptions have been published for *P. terlootii* (Henry Edwards) (last instar and pupa) (Comstock 1948); *P. flavofasciata* (Walker) and *P. juanita* (Strecker) (last two instars of each (Hodges 1971); and *P. gaurae* (J. E. Smith) (last instar and pupa) (Hodges 1971). The paucity of life history information is likely the result of the rarity of most *Proserpinus* species.

Proserpinus clarkiae (Boisduval) (Figs. 1–2) is a small, green, diurnal sphingid ranging widely through western North America (Hodges 1971). It is univoltine, with adults in spring or early summer depending on elevation and latitude. In California, *P. clarkiae* is abundant at localities in the far north and rare in the south. The purpose of this paper is to present the biology of this species and describe the early stages while comparing immature characters with those of related species.

METHODS

On 20 March 1988, I collected four adult female *Proserpinus clarkiae* in Gates Canyon, Solano Co., California, between 1350 and 1530 h. One female was placed in a 1000 ml beaker lined with a damp paper towel. The top of the beaker was closed, but not sealed, with a loose sheet of clear glass. The beaker was kept indoors where it was ⅓ to ½ illuminated by direct sunlight. When condensation appeared on the underside of the glass sheet, the glass was turned over. Oviposition onto the paper occurred only during periods of high activity, while the moth was in flight, predominantly between 1100 and 1600 h. Ova were laid



FIGS. 1–2. Adult *Proserpinus clarkiae*. **1.** Male, **2.** Female. Scale bar = 1.0 cm.

singly; ninety-two ova were produced by one moth between 21 and 22 March; oviposition ceased after 22 March. During subsequent years other females were induced to oviposit under the same conditions. The ova were stored in a dry beaker under indoor conditions at room temperature (15–21°C). Larvae were reared indoors and offered various plants in the Onagraceae. Late stage larvae were kept in a terrarium over two inches of sand with dry grass and plant debris on the surface; or over two inches of silty soil with stones and clay pots sunk slightly into the soil surface.

Preserved specimens (in alcohol) of ova (n=4), and first (n=7), third (n=1), fourth (n=4), and fifth instar (n=1) larvae are deposited in the collection of the Essig Museum of Entomology, University of California, Berkeley.

LIFE HISTORY

Ova (Fig. 3). Lime green, smooth, chorion transparent; round, oblong, slightly compressed laterally; mean = 1.14 × 0.89 mm, range = 1.1 × 0.93 to 1.19 × 0.85 mm (n=7) A day before eclosion, ova are predominantly yellowish, and the yellow larvae visible through the chorion, with remnant green yolk laterally.

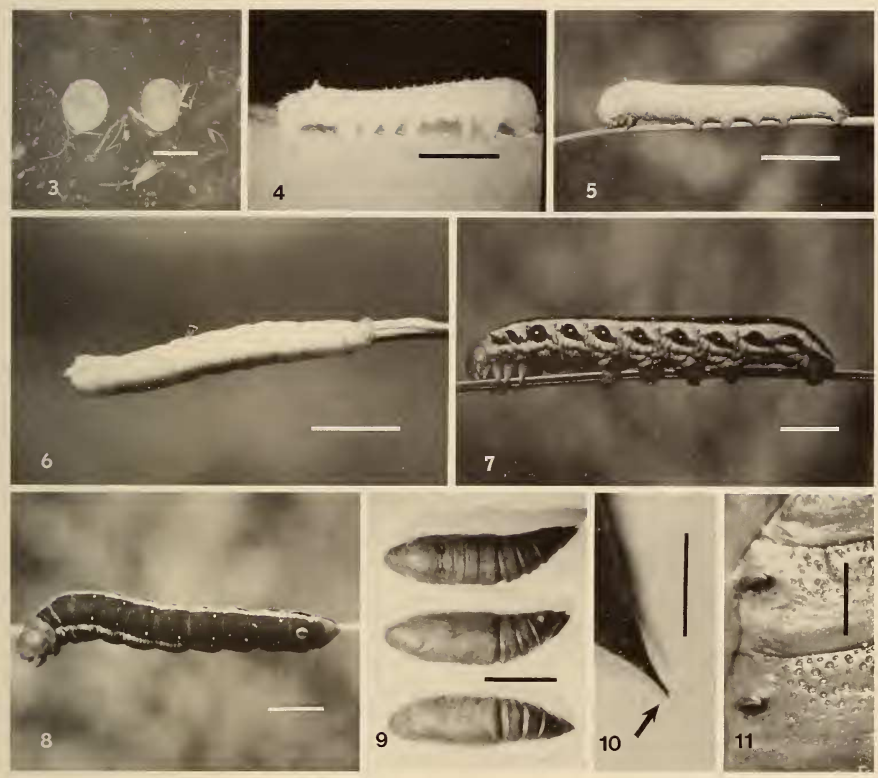
Larva: First instar (Fig. 4). Head: Yellowish green, width 0.63 mm (n=7). Body: Thoracic legs yellowish green. Ground color light green. Spiracles light green. Prolegs light green. Minute club-shaped scoli clear. Dorsolateral scoli on thoracic and abdominal segments 1 through 7 in longitudinal pairs (each scolus centered on anterior and posterior halves of segments). Anal horn absent, replaced by pair of scoli. Three longitudinal pairs of scoli along dorsolateral lines of terminal segment, caudal of anal scoli. Single, reduced, lateral scoli on abdominal segments, double on thoracic segments. A ventrolateral series of scoli in oblique pairs on abdominal segments. Anal shield dark green to pink. Mean length at eclosion 3.08 mm, range 3.02 to 3.17 mm (n=10).

Second instar. Head: Yellowish green, width 0.7 to 0.8 mm. Body: Thoracic legs yellowish green. Ground color green to yellowish green, caudal end slightly darker in some. Spiracles green. Faint pale green dorsolateral line along length of body to tip of terminal segment. Prolegs green to yellowish green. Anal prolegs dark green to slight pinkish. Anal shield pink to fuchsia. Anal horn absent. Late stadium length 11 to 12 mm.

Third instar. Head: Green, width 1.5 to 1.6 mm. **Body:** Thoracic legs pinkish. Ground color green. Whitish panicula profuse over body, each bearing a microscopic, clear seta from its center. Spiracles green. Dorsolateral band pale green. Prolegs green or pink to fuchsia. Anal prolegs fuchsia. Caudal end of terminal segment pinkish. Anal shield pink to fuchsia. Anal horn absent. Larvae variable in the amount of pink markings, if any. Late stadium length 14 to 18 mm.

Fourth instar (Figs. 5, 6). **Head:** Green to pink, width 2.2 to 2.6 mm. Body: Thoracic legs green to pink. Ground color green. Spiracles pink. Whitish panicula profuse over body, each with a microscopic clear seta. Dorsolateral stripe whitish, margined dorsally by dark green. Ventrolateral surface green, sometimes tinged pink. Ventral surface green or pinkish. Caudal end of terminal segment fuchsia. Anal prolegs and anal button fuchsia. Anal horn absent. Color variable, with the extent of pink shading on the ventral to ventrolateral surface, prolegs and head, grading from all green to all pink to fuchsia. Late stadium length 23 to 30 mm.

Fifth instar (Figs. 7, 8). **Head:** Light reddish brown, width 3.5 to 3.7 mm. **Body:** Coloration radically different from that of earlier instars, brownish pink to fuchsia. Panicula profuse over body, black dorsally, whitish ventrally, all bearing microscopic black setae from their centers. Prothoracic shield and thoracic legs reddish brown. Spiracles light gray. Dorsal surface dorsad of the dorsolateral line black to grayish black. Lone pinacula create a small cream dot just dorsal to the dorsolateral line, on the posterior margin of abdominal segments 1 through 7. A field of straw-cream laterally from dorsolateral line through ventrolateral line. Intersegmental area of thoracic and abdominal segments, ventrad of dorsolateral line, pinkish tinged with cream. Spiracles surrounded by oblong grayish black blotches extending obliquely (anterodorsal to posteroventral) over lateral surfaces of segments, surrounded by the lateral straw-cream color. In some specimens the oblique blotches form a heavy, continuous lateral band of interconnected oblique bars the length of the body, with a comparatively thin dorsolateral line and a broken, straw colored ventrolateral line. Large oblique oval spots of jet black surround abdominal spiracles 1 through 8, contained entirely within the oblique blotches. Ventral surface and prolegs brownish pink.



FIGS. 3–11. Early stages of *Proserpinus clarkiae*. **3.** Ova. Scale bar = 1.0 mm; **4.** First instar larva, lateral view. Scale bar = 1.0 mm; **5.** Fourth instar larva, lateral view; **6.** Dorsal view. Scale bar = 1.0 cm; **7.** Last (fifth) instar larva, lateral view; **8.** Dorsal view. Scale bar = 1.0 cm; **9.** Pupae: top, dorsal view; center, ventral view; bottom, lateral view. Scale bar = 1.0 cm; **10.** Cremaster, ventral view (note bifurcate tip). Scale bar = 1.0 mm; **11.** Right dorsolateral view of pupa, abdominal segments 2 and 3 showing pitting. Scale bar = 1.0 mm.

Anal button ringed in black, straw-cream with a dark reddish brown dot at the center. Anal horn absent. Early stadium length 26 to 33 mm, late stadium length 55 to 60 mm.

Pupa (Figs. 9–11). Length ranges from 20 to 26 mm, mean = 24 mm (n=7), width to 7 mm. Chestnut brown, tending darker brown caudally, with dark brown metathoracic protuberances on the dorsum. Cremaster conical, tapering to a sharp, bifurcated point (Fig. 10), contrasting sharply with the highly flattened structure described by Comstock (1948) for *P. terlootii*. Surface smooth; anterior half of each abdominal segment heavily pitted (Fig. 11).

RESULTS AND DISCUSSION

Eclosion commenced nine or ten days after oviposition. Upon eclosion, larvae fed on the chorion. First instar larvae ate only small portions of fresh, young *Oenothera hookeri* (Torrey & A. Gray) (Onagraceae) leaves, and high mortality was experienced. Artificially overcrowded larvae pinching each other with their mandibles, and reduced feeding on *O. hookeri* contributed to mortality. *Clarkia unguiculata* (Lindley) (Onagraceae) was accepted readily by larvae of all stages. I reared larvae to maturity on *Fuchsia* sp. (Onagraceae) obtained at a nursery. In addition, *Clarkia concinna* (Fischer & C. Meyers) was readily accepted by fourth and fifth instar larvae.

Boisduval (1852) assumed that *P. clarkiae* fed on Onagraceae based on the Old World *Proserpinus proserpina* (Pallas), whose habits were well known at his time. "We have given to this species the name of *clarkiae* by analogy, for we believe we can assure in advance that it nourishes itself of a plant of the Oenotherae family."

Species of *Proserpinus* and the related sphingid genera *Euproserpinus* Grote and Robinson and *Arctonotus* Boisduval are Onagraceae-feeders (Comstock & Dammers 1935, Comstock 1948, Hodges 1972, McFarland 1966, Tuskes & Emmel 1981), so the prediction that *P. clarkiae* should be found on plants of this family seemed warranted.

During the spring of 1988, Daniel Rubinoff, Lee Shoemaker, and I conducted extensive searches of dense stands of the annual *C. unguiculata* at Gates Canyon. On 9 April, Shoemaker located a second instar larva, and on 30 April, one each of fourth and fifth instar larvae of *P. clarkiae* were located by Rubinoff on *C. unguiculata*. I later discovered two *P. clarkiae* pupae in the Bohart Museum of Entomology at the University of California, Davis, bearing the labels: (1) "Marin Co., Fairfax, Food *Clarkia*, June 1940, Bred;" and (2) "Sonoma Co., Spring Mt., Food *Clarkia*, June 1940, Bred, J. S. Buckett collection."

I observed female *P. clarkiae* exhibiting oviposition behavior on an unidentified *Clarkia* species at Dardanelle, Tuolumne County, on 16 June 1991, and 10 miles east of McCloud, Siskiyou County, California, on 19 June 1988, but have not seen ova in the field.

Early instar larvae are cryptic on *Clarkia* foodplants, which often have fuchsia colored stems and petioles. Third and fourth instar larvae also strongly resemble the *Clarkia* fruiting bodies (which are present during larval development) in size, color, and shape. The fifth instar larva bears no resemblance to any part of the foodplant. At this stage of development, the larvae are quite large, and under normal circumstances, may consume several entire plants of most *Clarkia* species (because they are small), and may have to travel between plants. The broken pattern and straw colors of the fifth instar may serve as a form

of crypsis against the drying annuals and grasses among which the larva must search for foodplants. The late stage development of this insect, at most localities, coincides with the drying out of the grasses and annuals.

This drastic change in larval color and markings at late instar development appears to be characteristic of *Proserpinus* as well as *Euproserpinus* (Comstock & Dammers 1935, Tuskes & Emmel 1981) and *Arctonotus*. As in *P. clarkiae*, the penultimate larvae of *P. flavofasciata* and *P. juanita* are green with pale dorsolateral lines (Heitzman & Heitzman 1987, Hodges 1971). The mature larvae of these, as well as *P. gaurae* and *P. proserpina*, are marked like *P. clarkiae*, with the intricate pattern of blotches and lines of contrasting color. *Proserpinus proserpina* is depicted by Chinery (1989), with dark grey or brown dorsum, cream lateral field, prolegs, and venter, oblique black blotches surrounding the spiracles, and a caudal button of black, ringed in cream. I suspect that early instars *P. proserpina* are green with the dorsolateral line, but I haven't yet found confirmation of this in the literature. *Proserpinus gaurae* has oblique blotches of red, surrounded by white on a yellow-green field, and a "dark" ventral surface (Hodges 1971). *Proserpinus juanita* has a "brick red" ground color and white or cream dorsolateral and oblique lateral lines (Hodges 1971), and black lateral blotches in a cream field, with dark brownish prolegs and ventral aspect (Heitzman & Heitzman 1987; as depicted in a photograph), and black anal button surrounded with a white ring. *Proserpinus flavofasciata* is predominantly brown with black spots, with white and black bands (one each) surrounding the black caudal button (Hodges 1971). Preultimate instars of *P. terlootii* have not been described, but green with a light dorsolateral stripe is to be expected. *Proserpinus terlootii* may differ from its congeners by having a late stage similar to earlier stages, being predominantly green (Comstock 1948) and having the dark lateral blotches reduced to a small size. Still, a dorsal profusion of orange pinacula ("minute round spots," Comstock 1948) could give the larva a brownish color. Due to small foodplant size at some localities, late instar *Euproserpinus phaeton* (Grote & Robinson) may outgrow their hosts much like *P. clarkiae*. McFarland (1966) noted larvae of *E. phaeton* to be cryptic on the desert floor, against the debris of mature and senescing annuals. However, where *E. phaeton* does not outgrow its foodplant, late instar larval coloration remains cryptic and disruptive, such as on mature prostrate mats of *Camissonia bistorta* (Nutt. ex. T.&G.).

In captivity, pupation occurred six or seven weeks after eclosion. When mature larvae were maintained on two inches of sand with a surface layer of dry weeds and grass, pupation was aborted, and larvae

wandered over the surface of the sand until they died (presumably from desiccation). Pupation occurred in a cell against the under surface of stones, bricks, and clay pots resting on silty soil. The higher humidity presented by silt capped with solid objects may have been the critical factor for successful pupation and pupal survival. Larvae may be able to detect higher soil humidity near and under solid objects on the surface, and such cues may initiate burrowing. No attempts at burrowing were observed over the dry (and dusty) sand. Humidity may also be important to successful emergence as is the case for *E. phaeton* (Mcfarland 1966).

Insects reared from Del Puerto Canyon (1990) emerged in the spring of the following year. Emergence dates (n=5) ranged from 24 March to 3 April 1991. As with *P. terlootii* (Comstock 1948) and *E. phaeton* (Comstock 1938), some *P. clarkiae* pupae survived into a second year, suggesting the possibility of emergence delay until spring of a subsequent year.

Adults emerged between 0700 and 1300 h (n=4). Although adult *P. clarkiae* are as small as adult *E. phaeton*, they do not expand their wings upon emergence in the same manner as *E. phaeton* (McFarland 1966), where wing expansion is hydraulically forced up against gravity. *Proserpinus clarkiae* expands its wings in the manner of most moths, by allowing the wings to hang below the elevated and inclined body, while the insect clings to a near-vertical or overhanging substrate.

In the late morning of 29 March 1991, a resting female, having emerged about two hours earlier, extruded its papillae anales and maintained this posture for over an hour (until disturbed). This observation, along with the sexually dimorphic adult antennae (male antennae are larger and setose) (Figs. 1, 2), suggests probable pheromonal mate attraction in *P. clarkiae*. Males of *P. flavofasciata* appear to be attracted to pheromones (Reed et al. 1987).

Adult flight occurs between 1000 and 1700 h. Highest activity occurs in the afternoon between 1400 and 1600 h. Adults use a wide range of nectar sources, including *Clarkia* species (Onagraceae), *Vicia* species (Fabaceae), *Ribes aureum* (Pursh) (Grossulariaceae), *Cirsium* species (Asteraceae), *Eriodictyon californica* (Hook & Arn.) (Hydrophyllaceae), *Dichelostemma capitatum* (Salisb.) (Liliaceae), *Asclepias cordifolia* (Benth.) (Asclepiadaceae), *Salvia columbariae* (Benth.) (Lamiaceae) (all my observations), and *Stachys* species (Lamiaceae) (J. Powell pers. comm.).

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